

Dietary copper sulfate for control of gastrointestinal nematodes in goats

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Abstract

Prevalence of anthelmintic resistance in gastrointestinal nematodes (GIN) of goats has necessitated studies for alternative means of control. The objective was to determine the effectiveness of dietary copper sulfate for control of GIN in meat goats. Naturally infected buck kids received 0 (LC), 78 (MC) or 158 (HC) mg copper sulfate (CS)/kid daily mixed with concentrate supplement for 63 days. After 42 days the HC group was re-randomized into either the LC or MC treatment. In another study, naturally infected yearling does were offered trace mineral mix with and without CS and intake was estimated to be 140–200 mg CS/day. Goats grazed bermudagrass pastures and were rotated among two or three pastures to minimize pasture effects. Fecal egg count (FEC) and packed cell volume (PCV) were determined every 7 days in the first experiment and 14 days in the second experiment, and goats were weighed every 28 days. On Days 49 and 56 FEC were lower in the HC-treated kids (copper by day, $P < 0.02$), but FEC were similar on all other days in the first experiment and were similar between the two groups of does in the second experiment. Blood packed cell volume was similar among treatment groups throughout both studies. Body weight was greater in LC compared with MC or HC-supplemented kids on Days 42 and 63 (copper by day, $P < 0.04$). Body weights of does were similar on Days 0 and 56, but were reduced in those consuming trace mineral with CS on Day 28 (copper by day, $P < 0.03$). Dietary CS failed to control GIN in this study.

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1. Introduction

Control of gastrointestinal nematode infection (GIN) in goats has become a challenge because many have developed resistance to most approved anthelmintics (Miller and Craig, 1996; Zajac and Gipson, 2000; Terrill et al., 2001; Mortensen et al., 2003; Kaplan et al., 2005). A recent popular publication (Coleby, 2001) has

sparked the interest of producers in using up to 2 g or more copper sulfate daily to control GIN, specifically *Haemonchus contortus*. Recent studies have provided evidence that copper oxide wire particles can effectively and safely be used as an anthelmintic in growing lambs (Burke et al., 2004; Burke and Miller, 2006). Copper sulfate is more soluble than copper oxide (Ledoux et al., 1995). Sheep are susceptible to copper toxicity if levels of copper are too high in the diet. However, goats are less susceptible to copper toxicity. NRC (2007) recommendation on copper is 25 mg/kg dry matter intake. Studies reported that signs of copper toxicity were not apparent in growing goats supplemented with

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100 mg/day or less (Zervas et al., 1990; Solaiman et al., 2007). It is of interest to determine whether dietary copper can be used to decrease levels of infection of *H. contortus* in growing goats.

The objective of these studies was to determine the effectiveness of copper sulfate mixed in a feed or mineral supplement for control of GIN infection in goats.

2. Materials and methods

All experimental procedures were reviewed and accepted by the Agricultural Research Service Animal Care and Use Committee.

2.1. Experiment 1

In early summer at the USDA, ARS Dale Bumpers Small Farms Research Station in Booneville, AR, naturally infected commercial Boer buck kids, approximately 90 days of age, were assigned randomly to receive 0 (LC; $n = 13$), 78 (MC; $n = 11$) or 158 (HC; $n = 11$) mg copper sulfate (CS)/kid, which was mixed daily with 220 g supplement/kid (60% corn, 22% soybean meal, 13% cottonseed hulls, 4% molasses, 0.81% limestone, 0.37% dicalcium phosphate, 0.5% ammonium chloride, 0.15% trace mineral and vitamin premix, and 27.5 mg/kg lasalocid; 15% crude protein, dry matter basis). Goats were fed as a group. On Day 42 (Day 0 = first day of supplement) body weight of kids that received HC treatment tended to be lighter than other goats. Because these were privately owned goats and production was important, the HC goats were re-randomized into the LC and MC groups. At this time supplement was increased to 340 g/kid daily, while CS remained at 0 (LC) or 78 (MC) mg/kid. Kids grazed 1 of 3 primarily bermudagrass pastures previously grazed by small ruminants at a stocking rate of 9–11 kids/ha. To minimize differences in forage quality among pastures, goats were rotated between the 3 pastures every 7 days for 63 days. Kids were offered free choice water and trace mineralized salt (Land O'Lakes Sheep and Goat Mineral), which contained no added copper. Blood samples were collected via jugular venipuncture every 7 days for determination of blood packed cell volume (PCV) to monitor the level of anemia. Fecal samples were collected directly from rectum every 7 days to determine fecal egg counts (FEC) using the modified McMaster technique where each egg counted represents 50 eggs/g (Whitlock, 1948). Body weight was determined every 28 days. Individual goats were dewormed with levamisole (Levasol, 12 mg/kg) if PCV declined to

19% or below. Because of declining PCV on Day 21 (range of 15–24%), all kids were dewormed with moxidectin (Cydectin[®]; 0.4 mg/kg). Activity of the liver enzyme, aspartate aminotransferase (AST) in plasma (Booneville Community Hospital, Booneville, AR) was determined on Day 35. High plasma AST activity can indicate excess copper in the liver (Buckley and Tait, 1981). Two goats in the MC group died on Days 21 and 32 from haemonchosis and a fence accident, respectively. One HC goat died on Day 35 from unknown cause.

2.2. Experiment 2

In mid-February at the Booneville, AR site, naturally infected yearling Boer ($n = 20$) and Spanish ($n = 24$) does were blocked by breed and assigned randomly to receive a control trace mineral salt (62% dolomite, 18% kelp, 10% sulfur, and 10% Land O'Lakes Sheep and Goat Mineral; $n = 22$) or one with added CS (62% dolomite, 18% kelp, 10% sulfur, and 10% CS; $n = 22$) mixed at a rate of 10% with the commercial trace mineral mix for 56 days (Day 0 = first day of trace mineral supplement). Expected intake of trace mineral was 14–20 g/doe daily; therefore, does should have received 140–200 mg CS daily. Intake was difficult to measure because of wet weather conditions, but fresh trace mineral mix was offered daily to both groups. Does grazed similar grass pastures as in Experiment 1, which was overseeded with ryegrass for later winter grazing. Stocking rate was similar. To minimize differences in forage quality between pastures, goats were rotated between pastures every 7 days. Blood and fecal samples were collected every 14 days for determination of PCV and FEC. Body weight was determined every 28 days. Goats were dewormed with levamisole (Levasol, 12 mg/kg) if PCV declined to 19% or below. Plasma AST was determined on Day 42.

2.3. Statistical analysis

Data were analyzed using the mixed models procedure of SAS (1996). The mathematical model used for PCV, FEC, and body weight included treatment, day, treatment by day, and a repeated statement for day of measurement (Littell et al., 1996). Contrasts were determined using the PDIF option (all probability values for the hypothesis) in SAS when probability was less than 0.05%. FEC data were log transformed: $\ln(\text{FEC} + 1)$. Statistical inferences were made on transformed data and untransformed LS

means were presented. Plasma AST was analyzed using general linear models procedure.

In Experiment 1, if goats were dewormed on any day except Day 21 (all treated), FEC and PCV data points were removed the following 7, 14, and 21 days or remained for two separate analyses. Incidence of deworming was 7 LC, 5 MC, and 2 HC goats in addition to the Day 21 deworming. In Experiment 2, 1 Spanish doe and 4 Boer does or 4 control trace mineral and 1 CS trace mineral-supplemented does were dewormed and PCV and FEC data points were removed 14 and 28 days later. Chi squared analysis was conducted for both experiments to determine differences in number of dewormings for each treatment group.

3. Results

3.1. Experiment 1

For the restricted dataset FEC was similar among treatment groups between Days 0 and 42 (Fig. 1A). Similarly, when the entire dataset was analyzed (FEC included for those goats that were dewormed) FEC was similar among groups (data not shown). On Days 28 through 42 FEC were reduced in all groups in response to moxidectin administration. On Days 49 and 56 FEC were lower in the HC-treated kids (both HC LC and HC MC; copper by day, $P < 0.02$) and by Day 63 FEC increased in HC LC kids to that of the LC and MC groups. PCV was similar among treatment groups throughout the study (Fig. 1B). There was no difference in number of goats dewormed from each treatment group. Body weight was greater in LC compared with MC or HC-supplemented goats on Days 42 and 63 (copper by day, $P < 0.04$; Fig. 2). Plasma AST was similar among groups on Day 35 (69.1 ± 3.7 U/l).

3.2. Experiment 2

FEC were similar between trace mineral groups and ranged between 1400 and 2000 eggs/g between Days 0 and 56, respectively. FEC were lowest on Day 28 (800 eggs/g; day, $P < 0.001$). PCV was similar between trace mineral groups and ranged between a low of 23.9% on Day 0 and 26.3% on Day 56 (day, $P < 0.001$). PCV was lower in Boer compared with Spanish goats (24.1 vs. $27.3 \pm 0.5\%$, $P < 0.001$). No differences were detected in number of does dewormed from each treatment group. Plasma AST was similar between groups on Day 42 (70.3 ± 3.1 U/l). Body weights were similar on Days 0 (23.8 , 23.1 ± 0.8 kg) and 56 (31.8 ,

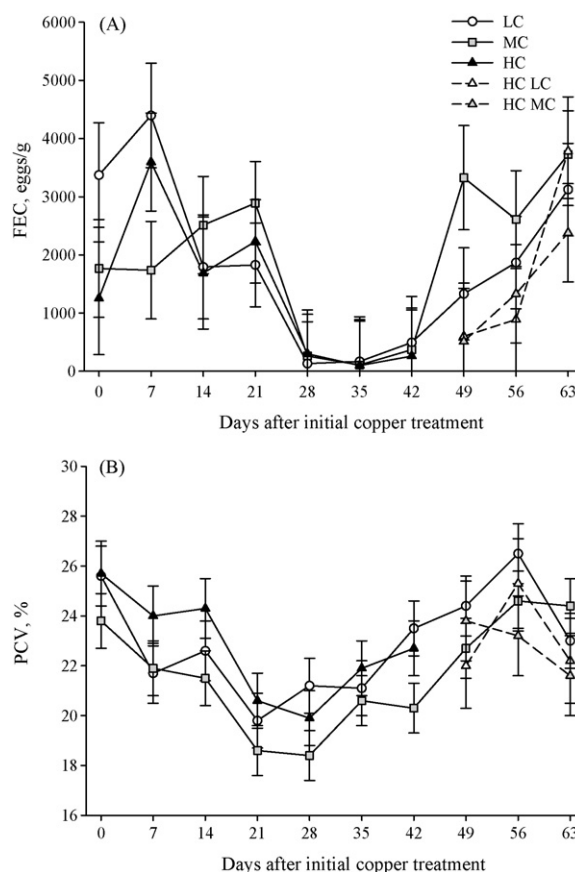


Fig. 1. Least squares means and standard errors of fecal egg counts (FEC; A) and packed cell volume (PCV; B) of buck kids treated with no copper sulfate (LC; $n = 11$; open circle), 78 (MC; $n = 13$; shaded square), or 158 mg copper sulfate (HC; $n = 11$; closed triangle) on Day 0. On Day 42 HC goats were re-randomized into LC (HC LC; $n = 5$; open triangle) and MC (HC MC; $n = 5$; shaded triangle) groups. All kids were treated with moxidectin on Day 21.

31.1 ± 0.8 kg), but reduced in goats consuming trace mineral with CS on Day 28 (28.4 , 26.5 ± 0.8 kg for control and CS trace mineral-supplement, respectively; copper by day, $P < 0.03$). The Boer does were heavier than the Spanish does ($29.5 > 25.3 \pm 0.8$ kg, $P < 0.001$).

4. Discussion

Use of dietary CS for control of GIN was ineffective in the current study. GIN infection levels were more severe in the younger buck kids than the yearling does, likely because of differences in season (warm vs. cool) and maturity. Typically, *H. contortus* is the primary GIN during summer months in Arkansas (Burke and Miller, 2006). Other GIN species may have been present during cooler months for the does in Experiment 2. Use of

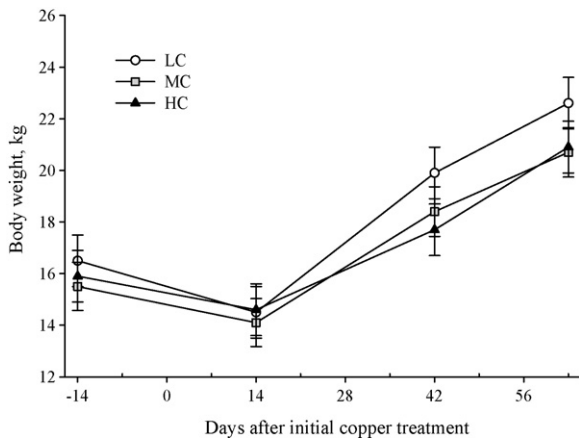


Fig. 2. Least squares means and standard errors of body weight of buck kids treated with no copper sulfate (LC; $n = 11$; open circle), 78 (MC; $n = 13$; shaded square), or 158 mg copper sulfate (HC; $n = 11$; closed triangle) on Day 0. On Day 42 HC goats were re-randomized into LC and MC groups, but data presented as HC. All kids were treated with moxidectin on Day 21.

copper sulfate as a drench in early studies was largely ineffective (Whitehurst and Swanson, 1942).

Copper requirements for growing kids with a body weight of 15 and 20 kg is estimated to be 12–13 mg/day and 16–18 mg/day, respectively, or 25 mg/kg DM feed (NRC, 2007). For growing does copper requirement is estimated to be 19–26 mg/day. Copper sulfate contains 25.4% copper. Therefore, buck kids supplemented with CS received 20 (MC) or 40 mg/day (HC) and does supplemented with CS received 36–51 mg/day of copper, dependent on intake of trace mineral mix. Levels provided were not intended to cause copper toxicity. Zervas et al. (1990) and Solaiman et al. (2007) reported no toxicity in goats supplemented with 60 mg copper/kg DM fed for 137 days or 100 mg/day for 84 days, respectively. Plasma AST activity in goats in the current study was within a normal range (Burke et al., 2005).

A popular remedy used by producers for GIN control includes the use of a mineral powder (dolomite, sulfur, CS, kelp) offered free choice, stressing the need for copper supplementation (Coleby, 2001). However, this recommendation was not based on scientific study. The author states that supplementation with CS should reach 1.25–2.5 g/day for goats raised in Australia. Complex mineral interactions with molybdenum, sulfur, selenium, and iron can bind copper, creating a copper deficiency, which could have influenced the recommendation of Coleby. Copper oxide wire particles have been administered to goats (Chartier et al., 2000; Burke et al., 2007) and sheep (Knox, 2002; Burke et al., 2004;

Burke and Miller, 2006) for control of *H. contortus*. The mechanism of action of copper oxide wire particles against *H. contortus* is unknown. Copper oxide is poorly absorbed compared with CS (Ledoux et al., 1995) and the particles lodge in the abomasum where adult *H. contortus* reside. Copper oxide wire particles exhibit a short-term (<7 days) effect on GIN infection (Burke et al., 2007) even though particles can be found in the gut for as long as 85 days (Suttle, 1987). In that study, copper oxide alleviated copper deficiency for up to 65 days. For both copper oxide wire particles, used in previous studies, and CS, used in the current study, it appears that a continuous supply of copper does not control GIN.

Because the buck kids were privately owned, weight gains were important. Thus, when body weight of HC-supplemented goats was lower than that of control goats after 42 days the HC supplementation was terminated. There may have been some influence of the copper supplementation in does on weight gain, as the 28 days body weight was reduced compared with control goats. Pregnant ewes administered 2 or 4 g of copper oxide wire particles gave birth to lighter weight twin lambs that gained more slowly than twin lambs from ewes that received no copper oxide (Burke et al., 2005). Copper supplementation at this research site could be associated with reduced gains in lambs or kids. In contrast, Solaiman et al. (2007) reported increased gains in meat goat kids administered 100 mg copper daily and Luginbuhl et al. (2000) observed no differences in weight gains of meat goat kids supplemented with 10 or 30 mg copper/kg DM feed.

5. Conclusion

Copper sulfate supplementation did not influence GIN of goats in this study. Therefore, the use of soluble CS for control of GIN is not recommended. Although the risk of copper toxicity is not high in goats, it may be influenced by mineral interactions, age, and breed types so toxicity could be an issue with extended feeding of CS. Weight gains may have been reduced in copper supplemented goats.

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